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Ionizing Radiation in Undergraduate Physics curricula: An analysis of Basil Bernstein's pedagogic device

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ABSTRACT

We present the results of a research analysis on the inclusion of ionizing radiation as a teaching subject in undergraduate Physics curricula in São Paulo State, following the new National Curriculum Guidelines for Initial Training of Basic Education Teachers came into force. For this purpose, we identified Physics undergraduate programs using the Brazilian Federal Government's e-MEC platform and retrieved their Curricular/Pedagogic Political Projects, syllabi and course catalog by accessing the respective websites. Based on Basil Bernstein's theory of the pedagogic device, especially the concepts of Official Recontextualizing Field (ORF) and Pedagogic Recontextualizing Field (PRF), we analyzed the way in which the new educational policies influenced the curricula of the programs investigated. Although ORF documents state the importance of including ionizing radiation in the PRF, only three (12% of the total of 25) programs offer a specific course on the topic. Given this scenario, the curricula should be updated to include ionizing radiation teaching in initial teacher education programs and ensure it is adequately addressed by providing times, spaces and teaching methodologies focused on the teaching-learning processes of this topic, allowing future teachers to recontextualize this subject in Basic Education.

Keywords: Ionizing radiation; curriculum; teaching degree in physics; Basil Bernstein.

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Las Radiaciones Ionizantes en los Currículos de Física Licenciatura: un análisis a partir del Dispositivo Pedagógico de Basil Bernstein

RESUMEN

Presentamos los resultados de un estudio que analizó la inclusión de la enseñanza de la Radiación Ionizante en el currículo de los cursos de Física en el estado de São Paulo/ Brasil, tras la promulgación de las nuevas Directrices Curriculares Nacionales para la Formación Inicial de Profesores de Enseñanza Básica. Para ello, identificamos los cursos de Física en la plataforma e-MEC del gobierno federal brasileño y recolectamos los Proyectos Políticos Curriculares/Pedagógicos, programas y planes de estudio accediendo a los sitios web de los cursos mapeados. Utilizando la Teoría del Dispositivo Pedagógico de Basil Bernstein, en particular los conceptos de Campo Recontextualizador Oficial (ORF) y Campo Recontextualizador Pedagógico (PRF), analizamos la forma en que las nuevas políticas educativas influyeron en la construcción de los currículos de los cursos investigados. Nuestro análisis mostró que, en los documentos que componen el CRO, hay argumentos sobre la importancia de la presencia de las Radiaciones Ionizantes en el PRC. Sin embargo, apenas 03 (12% del total de 25) cursos tienen una asignatura específica sobre Radiaciones Ionizantes. Frente a esto, abogamos por la actualización de los currículos para que la enseñanza de la Radiación Ionizante esté presente en los cursos de formación de profesores de Física y sea abordada de forma adecuada, proporcionando tiempo, espacio y metodologías de enseñanza dedicados a los procesos de enseñanza-aprendizaje de este tema, permitiendo a los futuros profesores recontextualizar este tópico curricular en la Educación Básica.

Palabras clave*:* Radiación Ionizante; currículo; licenciatura en física; Basil Bernstein.

1. Introduction

In recent years, Brazil has implemented a set of curricular guidelines for national education. Such is the case, for example, of the National Curriculum Guidelines for Initial Training of Basic Education Teachers enacted in 2015 and updated in 2019. In 2019, the *Base Nacional Comum para a Formação Inicial de Professores da Educação Básica* (National Common Curriculum for Initial Training of Basic Education Teachers – BNC-Formação) came into force.

Once published, these documents called upon the educational institutions responsible for teacher education and training to change their curricular course structure. A group of professionals from Education studies and other fields, linked to these courses, dedicated efforts to comply with the curricular policy, made explicit by the guidelines of the Brazilian National Council of Education (CNE).

Among other aspects, the curricular guidelines for teacher education and training courses establish the minimum course load. According to the 2019 guidelines, higher education courses must offer:

> I – 800 hours, for the common curriculum that comprises scientific, educational and pedagogic knowledge and underpins education and its articulations with systems, schools and educational practices; II – 1,600 hours for learning specific contents, components, thematic units and objects of knowledge established by the National Common Curricular Base, and for the pedagogic mastery of these contents (Conselho Nacional de Educação, 2019, p. 5).

Universities linked to the São Paulo State government, focus of this study, must also comply with deliberations made by the State Council of Education (CEE). According to CEE Resolution no. 126 (2014), Complementary Curricular Guidelines for Initial Training of Basic Education Teachers in Undergraduate Pedagogy courses, Normal School and Teaching degree courses, Teaching degrees must devote at least 30% of the total course load to didactic-pedagogic training. Supervised pre-service training and scientific-cultural activities are not included in this percentage (São Paulo, 2014).

Given these changes, those responsible for elaborating academic guiding documents, such as the Curricular Political Project (PPC), made changes in the curricular structures to comply with these guidelines and deliberations, making the principles set out in the norms fundamental for understanding which subjects should be included in the curriculum.

The curricular guidelines for Bachelor's and Teaching degrees in Physics should also be considered in this (re)fomulation (Conselho Nacional de Educação, 2001). According to this document, Undergraduate Physics curricula should cover, among other topics, contents from Classical Physics, General Physics and Modern Physics.

We agree with Vilela et al.'s (2020) observation that society is in constant transformation of thoughts, customs, and attitudes—a mutability that produces specific needs. Particularly, the teacher education process should prepare professionals able to promote changes in the teaching-learning processes in order to meet old and new demands for quality improvement in education. We must also "turn our attention to how the curriculum is organized so that reflecting on its different constitutive contents and conceptions is made possible" (Lopes et al., 2022, p. 15).

When referring to Modern Physics teaching, Silva & Almeida (2011) assert that, as the official documents defend a contextualized teaching linked to human culture and directly related to modern technologies, teaching 20th-century physics—which covers, among other contents, ionizing radiation—in high school is of undeniable importance. On the other hand, Machado & Nardi (2007, p. 91) emphasize the importance of updating the curriculum "... aiming to produce citizens capable of understanding the bases of numerous technologies present in everyday life."

Besides, teaching 20th-century physics content in high school fosters important debates among contemporary education researchers, in contemporary research and in school knowledge, since this knowledge permeates the discourse inside and outside universities and the nature of scientific work (Carvalho & Zanetic, 2004; Gil et al., 1988; Hilger & Moreira, 2012; Johansson et al., 2018; Lima et al., 2017; Telichevsky, 2015).

However, Oliveira et al. (2007) state that Physics teaching in Basic Education has not kept up with the technological advances of the last two decades. Moreira (2007, p. 172) also highlights the temporal lag of knowledge in schools, stating that "... it makes no sense that the physics taught in schools is restricted to (classical) physics, which only goes up to the 19th century." Pereira & Ostermann (2009) and Ostermann & Moreira (2000) address several justifications, forms of insertion and technologies to introduce and/or improve the inclusion of 20th-century Physics topics in Basic Education, some of which focus on ionizing radiation teaching.

We agree with Zimmermann & Bertani's (2003) statement that the comprehension and articulation of scientific and pedagogic contents in initial teacher education provide a training more adequate to the undergraduate's humanitarian and professional character. Moreover, the official documents reiterate the primacy of an up-to-date, contextualized teaching linked to human culture.

Several studies (Baumer et al., 2013; Monteiro et al., 2009; Sales & Leite, 2014) have shown that Basic Education teachers consider the inclusion of 20th-century physics content indispensable. However, they do not address such content in class due to lack of time—caused by the excessive content related to Classical Physics that must be explored—and training.

If we take, for example, the topic of ionizing radiation, Pizzolato & Adorno (2020), Eijkelhof (1996), among others, highlight the importance of approaching this topic during Basic Education to form a conscious citizen prepared for active participation in society.

A quick literature review shows that several authors argue in favor of including ionizing radiation content in the curriculum and practice of basic education Physics teachers. But this inclusion will only be effective if teachers are able and confident to teach this curricular topic. Thus, discussing Ionizing Radiation Physics, as well as knowledge related to science and mathematics, in Teaching degree courses is of paramount importance. For in order to recontextualize this knowledge in Basic Education, it must first be addressed in teacher training.

Ionizing Radiation teaching in teacher education is precisely our topic of interest here. Aware of the issues in Physics teacher training and about the indispensability of teaching ionizing radiation, we developed a study to analyze ionizing radiation teaching in the curriculum of Teaching degree in Physics courses using Basil Bernstein's pedagogic device. With this research, we seek to answer the following questions:

1) How are ionizing radiation-related contents included in the curricular structure of Undergraduate Physics courses in the state of São Paulo, in terms of semester of offering, contents covered and course load, after promulgation of the new National Curriculum Guidelines for Initial Training of Basic Education Teachers?

2) How does the new curricular guidelines, transmuted into codes; discourse; visible and invisible pedagogies; forms of classification/framing and other relevant characteristics, according to Basil Bernstein's pedagogic device, influence the construction of the curricula analyzed, especially regarding the inclusion of ionizing radiation content?

To answer these questions, we used Basil Bernstein's pedagogic device as an analytical reference.

2. Basil Bernstein's theory of the pedagogic device

Professor Emeritus of Sociology of Education at the Institute of Education, University of London, Basil Bernstein's (1924-2000) research scope involved the critical analysis of educational processes, curricula and the power relations between them.

In the field of curricular policies, several authors argue in favor of applying Bernstein's theory, especially for analyzing power relations, systematizing and understanding the production, distribution and recontextualization of scientific contents present in official documents using the pedagogic device as a theoretical framework. Bernstein's studies question the role of education in the cultural reproduction of class relations, stating that vertical and horizontal instructional and regulatory discourses, the relative autonomy of education, the production and reproduction of pedagogic discourse, the curriculum, pedagogies (visible and invisible), evaluations, restricted and elaborated codes, among other important concepts for efficient (or inefficient) pedagogic practices are ways to exert social control (Al-Ramahi & Davies, 2002; Ball, 1998; Heinzle & Bagnato, 2015; Lopes, 2005; Mainardes & Stremel, 2010; Nascimento, 1998; Neves et al., 2000; Silva et al., 2013; Singh, 2002).

His theory of the pedagogic device functions as a process analysis device by which specific fields of knowledge, contents, and disciplines are selected, transformed, and recontextualized in an educational setting into regulatory documents, curricula, school knowledge, and social relations. Bernstein's pedagogic device consists of distributive, recontextualizing, and evaluative rules. According to the author:

> These rules are themselves hierarchically related in the sense that the nature of the distributive rules regulates the recontextualizing rules, which in turn regulate the rules of evaluation. These distributive rules regulate the fundamental relation between power, social groups, forms of consciousness and practice, and their reproductions and productions. The recontextualizing rules regulate the constitution of the specific pedagogic discourse. The rules of evaluation are constituted in pedagogic practice (1996, p. 254).

Moreover, distributive rules specialize:

> ... the *production* of intellectual discourse to a particular field/context, with its own agents, positions, practice, and evaluations; the *reproduction* of pedagogic discourse to its own field/contet; and specializes manual discourse to its own field (Bernstein, 1996, p. 284).

Recontextualizing rules are those that "regulate the transformation of discourse within the field of the production of discourse into the field of its reproduction and exclude manual discourse from its dominant modalities" (Bernstein, 1996, p. 284). As a result, recontextualization "selectively appropriates, relocates, refocuses, and relates other discourses to constitute its own order and orderings" (Bernstein, 1996, p. 259).

Rules of evaluation, in turn, coordinate the transformation of discourse into pedagogic practice. In such a way that, by regulating the ways of transmitting scientific knowledge, the pedagogic discourse determines texts, times and spaces to be realized in the school, transmuting time into educational cycles and space and text into specific contents and contexts. Hence, the transmission of scientific knowledge is systematized through continuous evaluation (Morais & Neves, 2003).

Bernstein (1996) distinguishes two recontextualizing fields: the official recontextualizing field (ORF) and the pedagogic recontextualizing field (PRF). ORF is standardized by "specialized departments and sub-agencies of the State and local educational authorities together with their research and systems of inspectors" (p. 270), aimed at producing official pedagogic discourses (OPD), which regulate the production, recontextualization and distribution of the discourses and contents to be transmitted, as well as their realization.

PRF is regulated by departments of education (in schools and universities), research foundations, scientific journals and periodicals and aims to effectively direct and transmute the discourses produced into recontextualizing contexts. These processes are hierarchically related, since recontextualization depends directly upon the production of scientific knowledge and its reproduction cannot occur without being recontextualized. According to the author:

> To be complete we should state that the major activities of recontextualizing fields are creating, maintaining, changing, and legitimizing discourse, transmission, and organizational practices which regulate the internal orderings of pedagogic discourse (1996, p. 271).

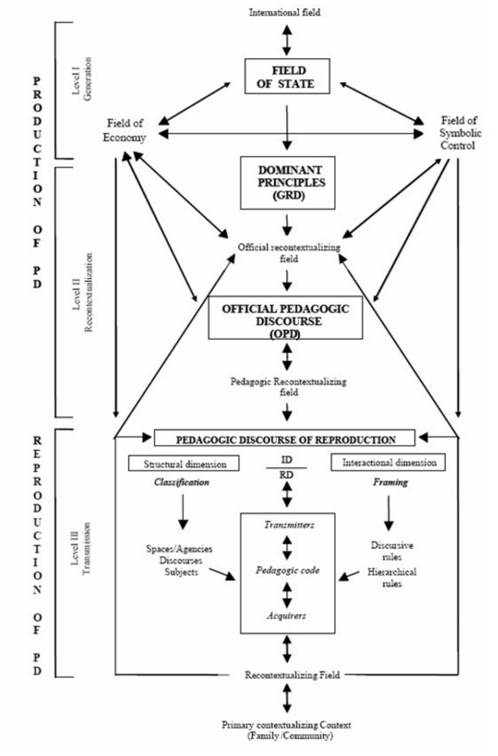
Bernstein also presents the concepts of visible and invisible pedagogies. Visible pedagogies present strong framings and classifications, whereas invisible pedagogies consist of weak framings and classifications. Classification refers "... to the degree of insulation between categories of discourse, agents, practices, contexts, and provides recognition rules for both transmitters and acquirers for the degree of specialization of their texts" (Bernstein, 1996, p. 300).

Framing, on the other hand, refers to the "... controls on the selection, sequencing, pacing, and criterial rules for the pedagogic communicative relationship between transmitter/acquirer(s) and provides the realization rules for the production of their text" (Bernstein, 1996, p. 300). Invisible pedagogies thus present degrees of insulation between discourse categories and less defined controls over the selection of content and forms of transmission. Conversely, visible pedagogies present greater delimitation between these aspects, becoming more evident throughout the guiding documents and pedagogic practices.

Figure 1, reproduced from Ramsarup (2005), intends to simplify the understanding and systematization of the pedagogic device.

Figure 1

Synthesis of Basil Bernstein's theory of the pedagogical device.



Source: Ramsarup (2005, p. 12).

The influence of the international field on the State, or rather on a country's government, acting directly upon the fields of symbolic control and production, is evident. Moreover, the dominant principles constitutive to the ORF and, therefore, the OPD are determined by the State. In the present work, the OPD can be defined as the guiding documents for Education, Physics Teaching, Teacher Training, etc.

By recontextualizing these primary official documents that make up the OPD into official Higher Education documents, such as curricula, discipline catalogue, PPP, PPC, among others, we form the PRF. This PRF recontextualize the OPD for the reproduction of discourse in the classroom, mediating times and spaces. In other words, the reproduction of discourse also depends on the classifications, times, contents, etc., and on the framings, spaces, and forms of communication standardized by the OPD and recontextualized into the PRF, which act directly on the transmitters and acquirers: of education, contents, teaching subjects, and the initial education of the student, the pre-service teacher, and the citizen.

We can thus explicitly observe how the processes of discourse construction that will be reproduced within the guiding documents and the classroom influence each other. Bernstein points out that symbolic control:

> ...is the means whereby consciousness is given a specialized form and distributed through forms of communication which relay a given distribution of power and dominant cultural categories. Symbolic control translates power relations into discourse and discourse into power relations (1996, p. 189).

The pedagogic device is thus “a *symbolic ruler of consciousness* in its selective creation, positioning, and oppositioning of pedagogic subjects. It is the condition for the production, reproduction, and transformation of culture” (Bernstein, 1996, p. 266).

Heinzle & Bagnato (2015) state that the process of curriculum construction involves political intentions, principles, choices, selections, and conceptions produced and recontextualized. Finally, several concepts present in Bernstein’s theory of the pedagogic device have been used in the analysis of research data, documents and their power relations. Among them, we have instructional discourse and regulatory discourse, restricted code and elaborated code, visible and invisible pedagogies, vertical discourse and horizontal discourse, relative autonomy of education, production and reproduction of pedagogic discourse, etc. (Lopes, 2005; Silva et al., 2013).

Coelho (2017), in a literature review article, presents some investigations on science curricula that have made use of Bernstein’s pedagogic device as a theoretical framework, especially regarding their process of recontextualization, which contemplates transformations onto the OPD (guidelines, educational documents), the pedagogic practice and the elaboration of didactic resources.

In the next section we discuss the research actions.

3. Study design

Our choice for a qualitative design is based in Godoy, who argues that:

> When a study is descriptive and seeks to understand the phenomenon as a whole, in its complexity, a qualitative analysis may be the most indicated. Even when our concern is to understand the web of social and cultural relations that are established within organizations (1995, p. 63).

Since our main concern focused on describing and understanding the inclusion of ionizing radiation in Undergraduate Physics curricula by means of a documental analysis, the choice is justified.

Among the different types of qualitative research, ours is documentary since we directed our attention to the curricular documents of HEIs to analyze the inclusion of ionizing radiation content. According to Kripka et al. (2015):

> ... documentary research is that in which the collected data are strictly derived from documents, with the objective of extracting information contained in them to understand a phenomenon; it is a procedure that uses methods and techniques for apprehending, comprehending and analyzing documents of the most varied types; it is characterized as documentary when this is the only qualitative approach, being used as an autonomous method (p. 58).

An important step in documentary research is choosing which documents to analyze. For Kripka et al. (2015) the choice depends on the study subject and the research problem. In our study, we chose to analyze the PPC, syllabi and discipline catalog of Undergraduate Physics courses.

We thus used procedures adopted in previous studies to conduct the present research (Bertoni & Londero, 2021). First, we restricted the research scope to in-class Undergraduate Physics courses offered in São Paulo due to the state's significant number of annual teacher training. Moreover, São Paulo stands out for having the largest Gross Domestic Product (GDP) and population in Brazil. It also has four state public universities (University of São Paulo (USP); State University of São Paulo (UNESP); University of Campinas (UNICAMP); Virtual University of the State of São Paulo (UNIVESP)), three federal universities (Federal University of ABC (UFABC); Federal University of São Carlos (UFSCAR); Federal University of São Paulo (UNIFESP)) and a larger set of private institutions. USP, UNESP and UNICAMP, together, are responsible for more than 35% of the academic and scientific production in Brazil, and 35% of their graduate programs were awarded a level of excellence by the Coordination of Superior Level Staff Improvement (CAPES).

Institutions were identified using the e-MEC platform, an official database of information related to Higher Education Institutions (HEIs) and undergraduate courses of the Federal Education System, maintained by the Ministry of Education (MEC). According to the MEC website:

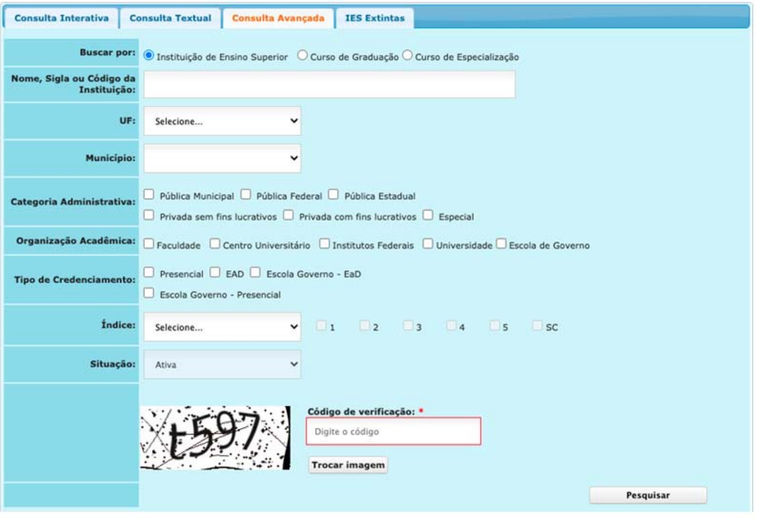
> The e-MEC was created for the electronic processing of regulatory processes. Higher Education Institutions can perform accreditation and reaccreditation, ask for authorization, recognition and renewal of recognition for courses through the internet. In operation since January 2007, the system allows institutions to open and monitor processes in a simplified and transparent manner (Ministério da Educação, 2022).

All requests for authorization, renewal and recognition of courses, accreditation and reaccreditation of HEIs and amendment processes, which are modifications to processes, are made on the e-MEC.

The platform allows several search filters, which aim to facilitate identifying the desired information, such as search by name or acronym, by academic organization (college/university/university center/federal institute) and by administrative category (public/private and federal/state/municipal). For undergraduate courses, searches can be performed by name, state, municipality, and as to the gratuity and modality. Through the platform, Brazilian citizens can check the status of courses and institutions at any time.

Figure 2

Layout of the e-MEC platform homepage.



Source: http://emec.mec.gov.br.

Firstly, we searched for the term "Physics" and filtered the results through the available resources to delimit the in-class Teaching degree courses offered in the state of São Paulo. Tables and charts were created to organize the information collected (name of the institution, administrative instance, year of creation, offering and teaching modality).

We then searched for the Political Pedagogical Projects (PPP), syllabi and discipline catalogue of the mapped programs on each institution's website. If virtual access to the documents was unavailable, we contacted the course coordinators via e-mail.

Afterwards, we read all the documents collected in full to identify the disciplines that address ionizing radiation, focusing on those that emphasize its teaching. We constructed tables containing the following information: name of the institution, discipline that addresses ionizing radiation, discipline credit (mandatory or elective), semester of offering, course load, topics of ionizing radiation addressed. To improve the analysis, we grouped the disciplines by their syllabus similarity.

Finally, we analyzed the collected data using Basil Bernstein's pedagogic device (see section 2), especially the concept of recontextualization. We sought to identify whether the new curricular policies described in section 1 influenced the course curricula analyzed, especially regarding ionizing radiation teaching.

4. Results and Discussion

Regarding HEIs, we identified a total of 25 Undergraduate Physics courses in the state of São Paulo. Of these, 28% (seven) are offered by the Federal Institute of São Paulo (IFSP), 22% (six) by UNESP, 15% (four) by UFSCAR, 11% (three) by UNICAMP, 7% (two) by USP and 4% (one) are offered by UFABC, the University of Taubaté (UNITAU) and the University of the West of São Paulo (UNOESTE).

Chart 1

Distribution of the disciplines identified by educational institution. The "---" sign indicates that it was not possible to identify the respective information.

Institution	Discipline	Discipline credit	Course load	Semester
UNESP	Modern Physics for High School Teachers	Mandatory	30	7
	Structure of Matter I		60	7
	Structure of Matter		120	5
	Structure of Matter		120	5
	Modern and Contemporary Physics		90	6
	Radiation Physics	Elective	30	---
	Ionizing Radiation Physics		60	5
UFSCAR	Modern and Contemporary Physics	Mandatory	90	7
	Modern Physics II		60	9
	Modern Physics I		60	8
	History of Classical and Contemporary Physics	Elective	60	---
	Introduction to Nuclear Physics		30	8
UNICAMP	Structure of Matter I	Mandatory	60	8
	Structure of Matter II	Elective	60	9
	Atomic and Molecular Physics		60	---
	Nuclear Physics		60	---
IFSP	Atomic and Molecular Physics	Mandatory Elective	64	7
	Atomic and Molecular Physics		60	6
	Nuclear and Particle Physics		60	7
	Interactions of Radiation with Matter		60	---
UFABC	Interactions of Radiation with Matter	Elective	60	---
	Introduction to Nuclear Physics		60	---
	Atomic and Molecular Interactions	Mandatory	36	4
USP	Structure of Matter I	Mandatory	60	7
	Particles – The Dance of Matter and Fields	Elective	60	4
UNITAU	Structure of Matter – Nuclear and Particle Molecular Physics	Mandatory	40	6

Source: elaborated by the author.

We observed a significant increase in the number of courses since the 1980s, since, at that time, the Southeast had only six courses, equivalent to 24% of the current total. When comparing the 1980s and 1990s, we see an increase of 183%, since by the late 1990s there were 11 undergraduate courses in Physics.

We found that 44% (12) of the courses belong to federal institutions, 4% (one) to private institutions, 44% (11) to state institutions and 4% (one) to municipal institutions.

As for the documents collected, we obtained 100% (12) of the discipline catalogue and PPPs (12) and 92% (11) of the syllabi from courses managed by federal institutions. In the case of state institutions, we obtained 100% (11) of the discipline catalogue, PPPs and syllabi. For municipal-managed courses, we obtained 100% (one) of the discipline catalogue but found neither their PPP nor their syllabi. The sole private institution with a Physics course identified has its discipline catalogue available, but not its syllabus or PPP.

Regarding the modality and offering, 64% (16) offer evening courses, 4% (one) daytime, 12% (three) daytime/evening and 20% (five) full-time courses.

As for ionizing radiation contents, we identified 26 disciplines covering the subject offered by seven HEIs. Chart 1 shows the distribution of the disciplines identified by educational institution.

As we can observe, 27% (seven) of the disciplines identified are offered by UNESP, 19% (five) by UFSCAR, 15% (four) by UNICAMP, 15% (four) by IFSP, 12% (three) by UFABC, 8% (two) by USP and 4% (one) by UNITAU. Moreover, 62% (16) are mandatory and 38% (eight) are elective disciplines. As for course load, 58% (15) have a course load equivalent to 60 hours. Courses with a course load equal to or greater than 60 hours represents 81% (21) of the sample, which shows the concern with the number of classes available to teach this topic—at least in those courses in which these disciplines are offered.

Most disciplines are offered after half the course has been completed, usually after the sixth semester. Only two disciplines are offered in the fourth semester and three in the fifth, equal to 19% of the total when added. The sixth and seventh semesters account for 15% (four) and 23% (six) of the disciplines offered, respectively. Finally, approximately 12% (three) of the disciplines are offered in the eighth semester and 8% (two) in the ninth period. However, 23% (six) of the disciplines analyzed lacked information on its period/semester of offering.

Chart 2 summarizes the so-called privileged contents, i.e., those mentioned with greater recurrence in the documents analyzed, related to ionizing radiation.

Chart 2

Contents mentioned with greater recurrence in the documents analyzed

Order number	Privileged content	Number of mentions
01	Radiation Properties	22
02	Particle Physics	14
03	X-rays	10
04	Nuclear Reactions	08

Source: elaborated by the author (2022).

Importantly, only four contents present relevant percentages for analysis, as the others express ratios of less than 30% of incidence.

By analyzing the HEIs' PPPs, we find the recontextualization of several assertions inferred by documents that govern Higher Education and Physics courses. We highlight, in particular, the direct influence of ORF-related documents: (i) Opinion no. 1304, of November 6, 2001, by the National Council of Education (CNE), which establishes the National Curriculum Guidelines for Physics Courses; (ii) CNE Resolution no. 1, of February 18, 2002, which established National Curriculum Guidelines for the Training of Basic Education Teachers (Bachelor and Teaching degree); (iii) CNE Resolution no. 2, of February 19, 2002, which established the duration and course load of Bachelor's and Teaching degrees, and training of Basic Education teachers at Higher Education; (iv) CNE Resolution no. 2, of June 1, 2015, which defined the National Curriculum Guidelines for Initial Training at Higher Education (undergraduate courses, pedagogical training courses for graduates and second teaching degree courses) and for continuing education; (v) Law no. 9394/96, the Law of Guidelines and Bases of National

Education; (vi) Law no. 13,005, of June 25, 2014, which establishes the National Education Plan; (vii) National curriculum parameters: secondary education.

The discourse present in these educational documents (ORF) is recontextualized in the PPPs into knowledge, competencies and skills to be acquired by undergraduates. Below we reproduce some excerpts from the PPPs analyzed to illustrate this recontextualization and explain the need for future teachers to have up-to-date knowledge of Physics, such as ionizing radiation.

> **The physicist** is a professional who, supported by solid and up-to-date knowledge, **must be able to address and approach new problems**. In a rapidly changing society, new social functions and new fields of activity for this professional are continuously emerging (Universidade Estadual de Campinas, 2018, p. 3, emphasis added).

> ... **they must be able to follow and understand scientific progress**, take a critical stance in relation to changes **and be able to dialogue with society about the risks and benefits that arise from scientific and technological advances.** Hence, the Physics professor and/or researcher must be a professional attentive to the demands of society, one who has investigative attitudes and is always prepared to share and circulate this practice. In addition to having a broad domain of scientific knowledge, qualities that are fundamental for a professional who will act as a transforming agent of society (Universidade Estadual de São Paulo, 2019, p. 5, emphasis added).

> Professional with mastery of the general principles and fundamentals of Physics, **familiar with its classical, modern and contemporary areas**, able to continue their studies in graduate programs in various areas, such as Teaching, Natural Sciences, Technological and others. In this context, the graduate is also able to establish relations between the various areas of knowledge and their applications through an **interdisciplinary** and contextualized view (IFSP-Birigui, 2015, p. 20, emphasis added).

> ... this proposed curricular structure is organized into three blocks of content. (a) Basic Education in Physics: which allows the undergraduate student to have a **solid background in Classical, Modern and Contemporary Physics** and its links with the Mathematical and Computational language, in addition to its relationship with Chemistry (Universidade Estadual de São Paulo, 2015, p. 4).

In the first excerpt, extracted from UNICAMP's PPP, we observe a partial reproduction of the ORF present in Opinion no. 1304/2001, excluding the ability to address and approach traditional problems. The second example, extracted from UNESP's PPP, highlights the future teacher's ability to monitor and understand the scientific changes, having the competence to communicate about the risks and benefits therein.

In our understanding, the ability to follow and understand the scientific changes will only be possible if initial training includes discussions of the most recent Physics topics, such as ionizing radiation (its risks and benefits), quantum mechanics, relativity, etc., as well as discussions about scientific epistemology.

The third excerpt explicitly states that the physicist must be "**familiar with its classical, modern and contemporary areas**", which includes ionizing radiation, and highlights the need for an "**interdisciplinary and contextualized view**." We understand this last discourse as a recontextualization of the ORF present in CNE Resolution no. 2/2019, which states in its Art. 13, § 4:

> In training courses for Primary and Secondary Education teachers, the 1,600 hours allocated to deepen and develop specific knowledge can be offered according to the curricular organization as follows: curricular components, **interdisciplinary** components or areas of study, as prescribed by the respective Curricular Political Project (PPC) (Conselho Nacional de Educação, 2019, p. 8, emphasis added).

In the fourth excerpt, extracted from UNESP – São José do Rio Preto's PPP, we observe a recontextualization of the ORF contained in CNE Resolution no. 2, of June 1, 2015, which explains in its Art. 3, § 6:

> The curricular project must be designed and developed via articulation between the Higher Education Institution and the Basic Education system, involving the consolidation of permanent state and district forums working closely together to support teacher training and must include I – **solid theoretical and interdisciplinary training of professionals** (Ministério da Educação, 2015, p. 5, emphasis added).

All PPPs analyzed present competencies and skills necessary for teacher education and performance in society. For example, let us see the discourse present in UNITAU's PPP.

> Provide the student with a solid knowledge base in Physics and related areas; Promote the necessary skills for effective and theoretically grounded practices in understanding socio-educational, psychological and pedagogic processes; Develop awareness of the role of Physics content in the student's education and understanding of the relations between Physics and other curricular components; Enable the student to analyze, critique and evaluate available textbooks and pedagogic materials, as well as to produce didactic resources for teaching; Stimulate critical thinking and a reflective posture in the undergraduate, promoting the training of professionals aware of their role in education, social, scientific and environmental development; Stimulate the investigative attitude and knowledge production about teaching and pedagogic practices; Promote the future teacher's reflexive attitude on their own knowledge and the search for self-education and professional development (2016, p. 14).

By recontextualizing norms and propositions, the PPPs (PRF) explicitly reproduce the distributive rules present in the official documents (OPD) in the form of justifications for including subjects and contents in Physics courses to explain the need for classic and updated contents, teacher training, approach to teaching-learning methodologies, among other concepts.

But despite featuring in the OPD and being recontextualized in the PRF, we found no effective inclusion of ionizing radiation content in all the HEIs curricula.

Despite numerous justifications, only 56% (14) of the Physics courses offer a discipline addressing ionizing radiation; and only three disciplines (12%) are exclusively dedicated to teaching this concept. Moreover, only two (8%) disciplines—Modern Physics for High School Teachers (UNESP – Guaratinguetá) and Ionizing Radiation Physics (UNESP – São José do Rio Preto)—highlight ways to adequately recontextualize the contents of Modern and Contemporary Physics in secondary education.

When analyzing the courses' PPP, we recognize the presence of rules of evaluation. UFSCAR – Araras' PPP states that:

> ... in the teaching-learning process, the act of teaching does not mean only transmitting knowledge, but also providing conditions for the construction, reconstruction and production of knowledge from common sense to scientific knowledge, never forgetting that teacher and student must be effective agents in the process. Thus, teachers must research not only what is to be discussed (content), but also the student's knowledge and reality (diagnostic evaluation) (p. 13).

On the other hand, UFSCAR's (São Carlos campus, evening course) PPP asserts that:

> Considering that evaluation practices must stem from a commitment of teachers with the current social reality, this project proposes alternatives that assume evaluation as a continuous, interactive and mediation process in structuring a knowledge endowed with meaning for the Physics teacher. This option is doubly important for graduates, as they should become multipliers of the pedagogic view that includes evaluation as an instrument of mediation in knowledge construction between teacher and student (p. 58).

Right after, the document cites the Rector's Office Ordinance no. 522, of 2006, which establishes the basis for evaluating teaching and learning:

> Art. 1 Evaluation is an integral and inseparable part of the educational act and must necessarily be based on the "action-reflection-action" process which comprises teaching and learning in the programs' curricular courses/activities, aiming to form "citizen professionals capable of an interactive and responsible action in today's society," characterized by its constant transformation (2006, p. 58).

It then states that:

> ... evaluation is inherent to the process of knowledge construction, both in the curricular dimension and at the institutional level; thus, the Teaching degree in Physics motivates and impels its professors to work with diversified evaluation instruments and use them as a tool for reflecting on their own educational practice. (2006, p. 58).

Corroborating the above, IFSP's (São Paulo campus) PPP argues that:

> According to the Institutional Development Plan, among the pedagogic principles are: research, integration between theory and practice, the curriculum built from the student profile, methodology based on problem situations that simulate reality, significant student learning, the teacher as a mediator of the teaching-learning process, didactic resources with materials that stimulate research and the search for new knowledge favoring investigative culture and the use of what is learned in real situations, and diagnostic, continuous, procedural and formative evaluation (p. 24).

UNICAMP's PPP, on the other hand, states that:

> Every few years, the curricular structure and the discipline syllabi are discussed. The Undergraduate Committee of the Institute of Physics "Gleb Wataghin" (IFGW) constantly discusses, evaluates and deliberates on the teaching and evaluation practices adopted at the IFGW, such as the introduction of project-based courses, peer-learning, courses with coordinated classes, etc. (p. 23).

Corroborating Bernstein (1996), we observe that evaluation is inseparable from the teaching-learning process and must occur in a continuous and formative manner in the legislative and recontextualizing spheres. Conclusive analysis of the documents, processes and practices are necessary to correctly identify the actions to be taken in each case to solve faculty and student needs and provide the appropriate structuring of knowledge and content endowed with values and meanings for the population.

As our analysis demonstrates, not many efforts have been made to include ionizing radiation content in teacher training courses, by means of official (OPD) and recontextualized (PRF) guiding documents. Although they argue for the inclusion of updated content and the need to provide effective teaching-learning processes so graduates are able to approach and recontextualize these contents in the classroom, they do not determine times, spaces or ways to address these contents, thus demonstrating some indifference towards the education and needs of graduates.

Distributive rules, which standardize the ORF, are evident in the reproduction and recontextualization of the OPD into the PPP. It is through recontextualizing rules that this transmutation occurs—whether of the OPD into PRF, or of the PRF into visible and invisible pedagogies. From these proposed delimitations recontextualized into classifications and framing emerge the rules of evaluation and pedagogic practices.

Finally, it is through symbolic control and therefore the power relations, financial and social interests acquired, perpetuated and encouraged by the State, that coordinating and standardizing discourses on education are construed. The ORF and the PRF thus recontextualize the distributive rules imposed by the State, culminating in a deficient and outdated pedagogic practice. By weakly alleging the need for an updated and effective education, the State discourse leaves cracks in the educational standardization that enable the perpetuation of traditional topics in detriment of contemporary physics content.

5. Final Considerations

Our analysis showed the presence of visible and invisible pedagogies that make up distributive, recontextualizing and evaluative rules in regulatory and pedagogic discourses, even if indirectly in some cases.

Thus, teacher training curricula must be updated to solve the problems identified, as to highlight the importance of 20th-century Physics by including proposals and justifications, providing means for the PRF to achieve its purposes in Undergraduate Physics courses. But it is the OPD, regulated by the ORF, that composes and (re)contextualizes, through the PRF, the teaching-learning process.

Bernstein's theory of the pedagogic device enabled our analysis of Undergraduate Physics curricula in the state of São Paulo. The ORF-composing documents (official documents regulating education, teacher training courses, etc.) provide us with arguments about the need for including ionizing radiation, as they are part of Modern and Contemporary Physics, in the PRF (PPP, PPC, curricula, etc.).

Despite the incisive propositions about the primacy of this topic in the PRF, however, only three (12%) courses offer a specific discipline to address it. The remaining courses offer disciplines with an average course load of 63 hours, which will be divided to address various areas of Physics, such as quantum mechanics and nuclear physics, together with ionizing radiation. Does this course load make up for the shortcomings reported by teachers and ensure familiarity with the theme of Modern and Contemporary Physics? Or, perhaps, is it necessary to change the excessive approach of Classical Physics in initial training?

Ionizing radiation must be adequately addressed by providing times, spaces and teaching methodologies focused on the teaching-learning processes of this topic so that it can be recontextualize in Basic Education. Teachers' unpreparedness and lack of confidence in approaching these contents will not be solved if the structural issues, prior to recontextualization in the classroom, go unsolved. Instruction on the topics of ionizing radiation and effective ways to recontextualize them in Basic Education are thus necessary already in the initial training, so teachers can develop tools to provide appropriate teaching-learning instruments for pedagogic practices.

Finally, we highlight the importance of Bernstein's theory for analyzing curricula and normative documents, as well as for understanding curricular issues by means of discourse analysis and symbolic control, thus meeting the needs of education, HEIs and students, to enable the training and education described in the ORF documents.

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References

Al-Ramahi, N., & Davies, B. (2002). Changing primary education in Palestine: pulling in several directions at once. *International Studies in Sociology of Education*, *12*(1), 59-76. https://doi.org/10.1080/09620210200200083.

Ball, S. J. (1998). Big policies/small world: an introduction to international perspectives in education policy. *Comparative Education*, *34*(2), 119-130. https://www.jstor.org/stable/3099796.

Baumer, A. L., Lawall, I. T., & Zanella, A. (2013, 21-25 de janeiro). *Professores em curso de formação continuada: perfil profissional, concepção sobre inovação curricular e sobre inserção de Física moderna e contemporânea em sala de aula* [Apresentação de trabalho]. XX Simpósio Nacional de Ensino de Física, São Paulo, São Paulo, Brasil. https://sec.sbfisica.org.br/eventos/snef/xx/sys/resumos/T0805-1.pdf.

Bernstein, B. (1996). *A estruturação do discurso pedagógico*: classes, códigos e controle. Vozes.

Bertoni, E. D., & Londero, L. (2021). A mecânica quântica nos currículos de Licenciatura em Física do sudeste do Brasil. *Revista de Enseñanza de la Física*, *33*(2), p. 205-212. https://doi.org/10.55767/2451.6007.v33.n2.35207.

Carvalho, S., & Zanetic, J. (2004). *Ciência e arte, razão e imaginação: complementos necessários à compreensão da Física moderna* [Apresentação de trabalho]. IX Encontro de Pesquisadores em Ensino de Física, Jaboticatubas, Minas Gerais, Brasil. http://www.sbf1.sbfisica.org.br/eventos/epef/ix/sys/resumos/T0094-1.pdf.

Coelho, F. B. O. (2017). Análise de currículos de ciências à luz da teoria de Bernstein. *Ciência & Educação*, *23*(3), 795-808. https://www.scielo.br/j/ciedu/a/rrg94cqpsyQKxkhj5bWbspc/?format=pdf&lang=pt.

Conselho Nacional de Educação. (2001). *Parecer nº CNE/CES nº 1304/2001 de 03 de abril de 2001*. Diretrizes Curriculares para os Cursos de Bacharelado e Licenciatura em Física. Diário Oficial da República Federativa do Brasil. http://portal.mec.gov.br/cne/arquivos/pdf/CES1304.pdf.

Conselho Estadual de Educação. (2014, 14 de junho). *Deliberação CEE n. 126/2014*. Altera dispositivos da Deliberação 111/2012. Diário Oficial do Estado de São Paulo. https://www.sieeesp.org.br/uploads/sieeesp/arquivos/delibera%C3%A7%C3%A3o/Delibera%C3%A7%C3%A3o%20CEE%20N%C2%BA%20126-14%20-%20Forma%C3%A7%C3%A3o%20de%20Docente.pdf.

Conselho Nacional de Educação. (2019, 23 de dezembro). *Resolução CNE/CP nº 02 de 20 de dezembro de 2019*. Define as Diretrizes Curriculares Nacionais para a Formação Inicial de Professores para a Educação Básica e institui a Base Nacional Comum para a Formação Inicial de Professores da Educação Básica (BNC-Formação). Diário Oficial da República Federativa do Brasil. http://portal.mec.gov.br/index.php?option=com_docman&view=download&alias=135951-rcp002-19&category_slug=dezembro-2019-pdf&Itemid=30192.

Eijkelhof, H. M. C. (1996). Radiation risk and science education. *Radiation Protection Dosimetry*, *68*, 273-278. https://doi.org/10.1093/oxfordjournals.rpd.a031878.

Gil, D. P., Senent, F., & Solbes, J. (1988). Análisis crítico de la introducción de la Física moderna en la enseñanza media. *Revista de Enseñanza de la Física*, *2*(1), 16-21. https://revistas.unc.edu.ar/index.php/revistaEF/article/view/15990/15814.

Godoy, A. S. (1995). Introdução à pesquisa qualitativa e suas possibilidades. *Revista de Administração de Empresas*, *35*(2), 57-63. https://www.scielo.br/j/rae/a/wf9CgwXVjpLFVgpwNkCgnnC/?format=pdf&lang=pt.

Heinzle, M. R. S., & Bagnato, M. H. S. (2015). Recontextualização do currículo integrado na formação médica. *Pro-Posições*, *26*(3), 225-238. http://dx.doi.org/10.1590/0103-7307201507811.

Hilger, T. R., & Moreira, M. A. (2012). A study of social representations of Quantum Physics held by High School students through Numerical and Written Word Association Tests. *Revista Electrónica de Investigación en Educación en Ciencias*, *8*(1), 52-61. http://www.scielo.org.ar/pdf/reiec/v8n1/v8n1a05.pdf.

Johansson, A., Anderson, S., Karlson, M. S., & Elmgren, M. (2018). "Shut up and calculate": the available discursive positions in quantum physics courses. *Cultural Studies of Education Science*, *13*, 205-226. http://dx.doi.org/10.1007/s11422-016-9742-8.

Kripka, R. M. L, Scheller, M, & Bonotto, D. L. (2015). Pesquisa documental na pesquisa qualitativa: conceitos e caracterização. *Revista de Investigaciones Unad*, *14*(2), 55-73. https://hemeroteca.unad.edu.co/index.php/revista-de-investigaciones-unad/article/view/1455/1771.

Lima, N. W., Ostermann, F., & Cavalcanti, C. (2017). Física quântica no ensino médio: uma análise bakhtiniana de enunciados em livros didáticos de Física aprovados no PNLDEM 2015. *Caderno Brasileiro de Ensino de Física*, *34*(2), 435-459. https://doi.org/10.5007/2175-7941.2017v34n2p435.

Lopes, A. C. (2005). Política de currículo: recontextualização e hibridismo. *Currículo Sem Fronteiras*, *5*(2), 50-64. https://www.curriculosemfronteiras.org/vol5iss2articles/lopes.pdf.

Lopes, E. S., Leite, F. A., & Hermel, E. E. S. (2022). Das teorias de currículo às concepções de Experimentação: contradições eminentes em PPCs de Institutos Federais. *Revista de Ensino de Ciências e Matemática*, *13*(1), 1-19. https://doi.org/10.26843/rencima.v13n1a17.

Machado, D. I., & Nardi, R. (2007). Construção e validação de um sistema hipermídia para o ensino de Física moderna. *Revista Electrónica de Enseñanza de las Ciencias*, *6*(1), 90-116. http://reec.uvigo.es/volumenes/volumen06/ART6_Vol6_N1.pdf.

Mainardes, J., & Stremel, S. (2010). A teoria de Basil Bernstein e algumas de suas contribuições para as pesquisas sobre políticas educacionais e curriculares. *Revista Teias*, *11*(22), 1-24. https://www.e-publicacoes.uerj.br/revistateias/article/view/24114/17092.

Ministério da Educação. (2015). *Resolução nº 2, de 1º de julho de 2015*. Define as Diretrizes Curriculares Nacionais para a formação inicial em nível superior (cursos de licenciatura, cursos de formação pedagógica para graduados e cursos de segunda licenciatura) e para a formação continuada. Ministério da Educação. http://portal.mec.gov.br/docman/agosto-2017-pdf/70431-res-cne-cp-002-03072015-pdf/file.

Ministério da Educação. (2022). *Cadastro Nacional de Cursos e Instituições de Educação Superior: Cadastro e-MEC*. Ministério da Educação. http://bit.ly/3F3puqh.

Monteiro, M. A., Nardi, R., & Bastos Filho, J. B. (2009). A sistemática incompreensão da teoria quântica e as dificuldades dos professores na introdução da Física Moderna e Contemporânea no Ensino Médio. *Ciência & Educação*, *15*(3), 557-580. https://www.scielo.br/j/ciedu/a/bqMYJGjV6zGgMm7N6FpBWFQ/?format=pdf&lang=pt.

Morais, A. M., & Neves, I. P. (2003). Processos de intervenção e análise em contextos pedagógicos. *Educação, Sociedade & Culturas*, *19*, 49-87. https://doi.org/10.34626/esc.vi19.

Moreira, M. A. (2007). A Física dos quarks e a epistemologia. *Revista Brasileira de Ensino de Física*, *29*(2), 161-173. https://www.scielo.br/j/rbef/a/8vfnKnySGmWxDKq8dzbwqjP/?format=pdf&lang=pt.

Nascimento, T. M. P. (1998). *Programas e sua recontextualização pelos professores: uma análise sociológica no âmbito da disciplina de físico-química do 9º ano de escolaridade* [Tese de mestrado em educação – Ciências, Universidade de Lisboa]. https://repositorio.ul.pt/handle/10451/42882?locale=en.

Neves, I. P., Morais, A. M., Medeiros, A., & Peneda, D. (2000). Os discursos instrucional e regulador em programas de ciências: estudo comparativo de duas reformas. *Revista Portuguesa de Educação*, *13*(1), 209-245. https://revistas.rcaap.pt/rpe/issue/view/1418/335.

Oliveira, F. F., Vianna, D. M., & Gerbassi, R. S. (2007). Física moderna no ensino médio: o que dizem os professores. *Revista Brasileira de Ensino de Física*, *29*(3), 447-454. https://www.scielo.br/j/rbef/a/rh5x6dG35fJrV87r99L5PmK/?format=pdf&lang=pt.

Ostermann, F., & Moreira, M. A. (2000). Uma revisão bibliográfica sobre a área de pesquisa "Física moderna e contemporânea no ensino médio". *Investigações em Ensino de Ciências*, *5*(1), 23-48. https://ienci.if.ufrgs.br/index.php/ienci/article/view/600/390.

Pereira, A. P., & Ostermann, F. (2009). Sobre o Ensino de Física Moderna e Contemporânea: uma revisão da produção acadêmica recente. *Investigações em Ensino de Ciências*, *14*(3), 393-420. https://ienci.if.ufrgs.br/index.php/ienci/article/view/349/216.

Pizzolato, N, & Adorno, D. P. (2020). Informal physics teaching for a better society: a mooc-based and context-driven experience on learning radioactivity. *Journal of Physics: Conference Series*. https://doi.org/10.1088/1742-6596/1512/1/012040.

Projeto Político Pedagógico. Instituto de Física de São Paulo, Birigui, 2015.

Projeto Político Pedagógico. Instituto de Física de São Paulo, São Paulo, 2018.

Projeto Político Pedagógico. Universidade de Taubaté, Taubaté, 2016.

Projeto Político Pedagógico. Universidade Estadual de Campinas, Campinas, 2018.

Projeto Político Pedagógico. Universidade Estadual de São Paulo, São Paulo, 2015

Projeto Político Pedagógico. Universidade Estadual de São Paulo, São Paulo, 2019.

Projeto Político Pedagógico. Universidade Federal de São Carlos, Araras, 2015.

Projeto Político Pedagógico. Universidade Federal de São Carlos, São Carlos, 2013.

Ramsarup, P. (2005). *Cases of recontextualising the environmental discourse in the national curriculum statement (R-9)* [Thesis of masters in education - Environmental education, Rhodes University]. https://commons.ru.ac.za/vital/access/services/Download/vital:1444/SOURCEPDF?view=true.

Sales, N. L. L., & Leite C (2014). *Os três momentos pedagógicos na formação Continuada de professores: discutindo ensino de Física moderna e contemporânea* [Apresentação de Trabalho]. XV Encontro de Pesquisa em Ensino de Física, Maresias, São Paulo, Brasil.

Silva, A. C., & Almeida, M. J. P. M. (2011). Física Quântica no Ensino Médio: O que dizem as pesquisas. *Caderno Brasileiro de Ensino de Física*, *28*(3), 624-652. https://doi.org/10.5007/2175-7941.2011v28n3p624.

Silva, P., Morais, A. M., & Neves, I. P. (2013). O currículo de ciências no 1o ciclo do ensino básico: estudo de (des)continuidades na mensagem pedagógica. *Revista Portuguesa de Educação*, *1*(26), 179-217. https://doi.org/10.21814/rpe.3258.

Singh, P. (2002). Pedagogising Knowledge: Bernstein‟s theory of the pedagogic device. *British Journal of Sociology of Education*, *23*(4), 571-582. https://doi.org/10.1080/0142569022000038422.

Telichevesky, L. (2015). *Uma perspectiva sociocultural para introdução de conceitos de Física Quântica no Ensino Médio: Análise das interações discursivas em uma unidade didática centrada no uso do interferômetro virtual de Mach-Zehnder* [Dissertação de mestrado em ensino de física, Universidade Federal do Rio Grande do Sul]. Lume: Repositório Digital. https://lume.ufrgs.br/handle/10183/114826.

Vilela, P. S. J., Sousa, R. C., Aranha, C. P., & Guerini, S. C. (2020). Reflexões sobre a formação inicial de professores de Física na UFMA. *Revista de Ensino de Ciências e Matemática*, *11*(5), 261-280. https://doi.org/10.26843/rencima.v11i5.2540.

Zimmermann, E., & Bertani, J. A. (2003). Um novo olhar sobre os cursos de formação de professores. *Caderno Catarinense de Ensino de Física*, *20*(1), 43-62. https://periodicos.ufsc.br/index.php/fisica/article/view/6563/60477.